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Identifying Austria's Implicit Monetary Target: An Alternative Test of the "Hard Currrency' Policy"

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ABSTRACT

One simple test of the long-run viability of an exchange-rate peg, which complements tests based on market expectations, is to ask whether the implicit inflation target of the pegging country is the same as that of the anchor country. If the implicit inflation targets of the two countries are different, the peg's long-run credibility can be rejected. The implicit inflation target is defined as the policy-implied, trend rate of inflation. The proposed test is applied to the Austrian experience with a 'hard currency' policy aimed at targeting its exchange rate with the Deutsche mark.

KEYWORDS:. Exchange Rate Peg, Inflation Targets

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Introduction

One way to determine whether a hard currency-the fixing of one's exchange rate to a low inflation country-is credible is to examine the implicit expectations measured from forward rates. Svensson (1991) constructed a credibility test that uses the uncovered interest rate parity condition as a measure of market expectations in order to determine the probability that an exchange rate target range will be maintained throughout the life of a forward contract. The test, commonly known as the "simplest" test for target zone credibility, consists of examining whether or not forward exchange rates fall within the announced exchange rate band. If the forward rates fall outside the band, then credibility is rejected. Forward foreign exchange contracts, however, generally are written to mature in a year or less. Svensson (1994) has addressed the need to evaluate longer-run market expectations of inflation by filtering yield-curve data to arrive at an estimate of expected inflation throughout the life of long-term government bonds.

In our evaluation of a country's inflation outlook and the future prospects of its exchange-rate peg, we ask whether the implicit inflation target in the country pursuing a hard-currency policy is the same as that in the anchor country. If the implicit inflation targets of the two countries are substantially different, credibility can be rejected. The implicit inflation target or baseline inflation rate is defined as a policy-implied, trend rate of inflation. Unlike Svensson's test, which measures exchange rate credibility in terms of implicit market expectations, our proposed test consists of estimating an implicit inflation target based on current and past monetary settings. The test attempts to answer whether the hard currency policy is a sustainable policy under the current monetary regime. If the implicit inflation target of the pegging country is considerably higher than the target of the anchor country, then the hard-currency policy is not sustainable and therefore lacks credibility.

The objective of this paper is to evaluate the success of the Austrian hard-currency policy by comparing its implicit inflation target with Germany's corresponding rate. Austria is often viewed as a 'pilot example' of a small country joining the European Monetary

System (EMS). The Austrian National Bank has pursued a 'hard currency' policy by pegging the schilling to the Deutsche mark since the breakdown of the Bretton Woods System. The schilling's stability, together with Austria's inflation performance during the 1980s and 1990s, suggests that the hard-currency policy is credible within financial markets. This paper seeks to highlight the basis of that credibility – similar long-run target rates of inflation across the two countries.

The indicator model of Dueker and Fischer (1994) is used to measure the implicit long-run target rates of inflation in the two countries. The indicator model aims to inform policymakers on a timely basis of the likely effect of current changes in the policy instrument on the implicit inflation target. Therefore, if Austria's implicit inflation target has been consistent with Germany's target, our methodology tells policymakers whether current monetary settings (short-term interest rates) are geared towards maintaining the target.

In addition, the methodology allows for multiple nominal target variables and shifts in the weights attached to each objective. Thus, we may apply the indicator model to both Germany, where the Bundesbank is primarily concerned with the domestic price level, and Austria, where the National Bank's primary objective to maintain an exchange-rate peg vis-à-vis Germany. The primary hypothesis is that Austria acquired credibility for its exchange-rate peg by adjusting its interest-rate differential with Germany in a manner that suggests: 1) strong responses to deviations from the exchange-rate target; 2) a desire to maintain Austrian inflation close to that in Germany.

The paper is organized as follows. The next section outlines Austria's 'hard currency' policy and reviews its inflation record relative to Germany's. The third section presents the indicator model of Dueker and Fischer (1994) and its application to Austria and Germany. The model's main features –implicit inflation targets and model-implied feedback mechanisms– are also discussed. The fourth section contains the main findings from our indicator model for Germany and Austria and provides goodness-of-fit tests of the indicator model. The final section concludes.

II Austria's 'Hard-Currency' Policy

The Austrian National Bank adopted the hard-currency policy in 1974. Figure 1 reveals that the schilling has been revalued twice and that since 1981 has fluctuated within a narrow band with respect to the Deutsche mark. At the time of the first oil shock, the schilling was revalued upwards against the Deutsche mark despite weak macroeconomic fundamentals. The intention was to signal a stable monetary policy and constrain wage growth over the medium term. The schilling was revalued for a second time in response to the second oil shock during the 1979-1981 period. Hochreiter and Winckler (1995) contend that this last revaluation of the exchange rate to the Deutsche mark triggered an adjustment process that now makes Austria part of an optimal currency area with Germany. Policymakers sought to induce an increase in the degree of real wage flexibility in the Austrian economy, so that real-wage adjustment would become the instrument for maintaining Austrian competitiveness in the face of shocks, rather than exchange-rate adjustment.

The credibility of the hard currency policy was tested during Germany's reunification process, which forced Austria's policy to take on higher than desired interest rates. Austria coped with these strains without abandoning its exchange-rate peg against the Deutsche mark. The schilling came away unharmed from the EMS currency crises of September 1992 and August 1993. The lack of market speculation against the Austrian schilling during this period suggests that the hard-currency policy is recognized by financial markets.

The Austrian National Bank's exchange rate policy consists of adjusting its interest-rate differential with Germany. In general the two market rates have moved in tandem, however Austrian short-term rates have been considerably more volatile. As a result of growing confidence in the Austrian schilling, a negative short-term interest rate differential between Austrian and German rates opened in mid-1992. The unusual negative 'country risk' premium against the anchor country has helped to induce a relatively large short-term capital outflow from Austria to Germany.

Before the introduction of the hard-currency policy, the inflation differential between Austria and Germany was not large on average. As can be seen from Figure 2, however, Austrian inflation before 1974 was more volatile. The same graph also shows that for the greater part of the hard-currency policy, Austrian inflation has followed German inflation except on two occasions. The first stemmed from the 1973 oil shock, which hit Austria particularly hard. The second episode occurred in 1983-85 when Austria, as described by Hochreiter and Winckler (1995), was subject to an idiosyncratic supply shock arising from a crisis within nationalized industries.

Although the Bundesbank does not announce formal inflation targets, its informal targets indicate what the profile of the implicit inflation targets should be for the two countries. The Bundesbank's informal inflation targets are documented in von Hagen (1994) and reproduced in Table 1. From 1975 to 1985, the Bundesbank referred to the informal inflation target as 'unavoidable inflation,' and this varied from year-to-year. Since 1986 the Bundesbank has defined a fixed, unconditional inflation target of 0-2 percent. This target range for inflation was not maintained, however, in the aftermath of German reunification when inflation briefly rose above four percent.

III Description of the Empirical Model

We begin with a general empirical model and show which features and parameters are relevant for an empirical characterization of German and Austrian monetary policy.[1] The German model takes the quarterly change in the short-term interest rate as the policy instrument, whereas the Austrian model uses the interest-differential with Germany as the policy instrument variable used to maintain the exchange rate. Both empirical models take the quarterly interest-rate change, combine it with a forecast of the relationship between

[1]Dueker and Fischer (1994b) provide a non-technical survey of how the indicator model relates to McCallum's (1993) monetary feedback mechanism.

interest-rate changes and inflation and call this "intended" inflation for the quarter. Assuming that the forecasts we derive mirror the consensus forecasts of the time, our intended inflation variable should reflect the policy intentions of the central banks across time. Furthermore, our empirical models can explain fluctuations in intended inflation from three distinct sources: the first source is variation in the baseline inflation target; the second source is intended inflation above or below the baseline rate in the short run to maintain a price level target; the third source recognizes that, in a small open economy, the central bank may intervene to keep the exchange rate within a comfort zone.

The following equations incorporate these three potential motives for modifying short-run intended inflation. Several parameters are assumed to be subject to discrete changes via markov switching, since, for example, the Austrian National Bank's degree of response to exchange-rate developments has likely shifted over time, depending on its tolerance for changes in the exchange rate. We also allow for markov switching in the variance of the error terms, since interest rates are often thought to be conditionally heteroskedastic. The model realistically allows for feedback from several objectives (the domestic price level and the exchange rate) and for shifts in the weights attached to each objective. Similarly, the implicit long-run inflation targets may not be constant across time either. Also, the extent to which the central banks target a path for the price level, as opposed to targeting a rate of inflation period-by-period, may be subject to change. In equations (1)-(4) below, i stands for the short-term interest rate (or interest-rate differential for Austria), P for the price level, $\widehat{P}$ is the target price level conditional on the values of the markov state variables, and $\widetilde{P}$ is the expected target level, not conditional on the values of the state variables. Similarly $\widehat{e}$ is the baseline exchange rate (in logs) conditional on the values of the state variables, and $\widetilde{e}$ is the baseline rate not conditional on the values of the state variables. In the model for Germany the Deutsche mark/ U.S. dollar exchange rate is used, whereas in the Austrian model we use the schilling/ Duetsche mark exchange rate.

We allow for three state variables subject to markov switching:[2] $S1$ for parameters related to inflation and/or price level targeting; $S2$ for parameters related to exchange-rate targeting; and $S3$ for heteroskedasticity.[3] In equations (1-4), the notation $\alpha(Si)$ indicates that parameter α is subject to markov switching governed by state variable Si. In equations (3), (5) and (6), Y_{t-1} denotes available information at time t-1.

$$\begin{aligned}
\text{Interest Rate:}\Delta ln(1+i)_t &= -\lambda_0(S1_t) + \Delta ln\left((1+i)^{\cdot}P\right)_{t|t-1} - \lambda_1(S1_t)[ln\widetilde{P} - lnP]_{t-1} \\
&\quad -\lambda_2(S2_t)[ln\widetilde{e} - lne]_{t-1} + \widehat{\epsilon}(S1_t, S2_t) \qquad (1) \\
&\quad \widehat{\epsilon}(S1_t, S2_t) \sim \text{student-}t \\
&\quad \text{var}[\widehat{\epsilon}(S1_t, S2_t)] = \sigma^2(S3_t)\frac{n}{n-2} \\
\text{Target Price Level: } ln\widehat{P}_t(S1_t) &= \lambda_0(S1_t) + \delta_1(S1_t)ln\widetilde{P}_{t-1} + (1-\delta_1(S1_t))lnP_{t-1} \qquad (2)
\end{aligned}$$

[2]The basic filtering and smoothing algorithms for a markov-switching model are discussed in Hamilton (1988, 1989).

[3]Kim (1993) notes that markov switching in the variance is an adept alternative to GARCH models for modeling conditional heteroskedasticity or "ARCH" effects.

$$
\begin{aligned}
\text{Expected Target: } ln\widetilde{P}_t &= \sum_{i=0}^{1} \text{Prob}(S1_t = i \mid Y_t) ln\widehat{P}_t(S1_t = i) && (3)\\
\text{Baseline Exch. Rate: } ln\widehat{e}(S2_t) &= \delta_2(S2_t) ln\widetilde{e}_{t-1} + (1 - \delta_2(S2_t)) ln e_{t-1} && (4)\\
\text{Expected Baseline: } ln\widetilde{e}_t &= \sum_{j=0}^{1} \text{Prob}(S2_t = j \mid Y_t) ln\widehat{e}_t(S2_t = j) && (5)\\
\text{Prob}(S1_t = i, S2_t = j, S3_t = k \mid Y_{t-1}) &= \text{Prob}(S1_t = i \mid Y_{t-1}) \cdot\\
&\cdot \text{Prob}(S2_t = j \mid Y_{t-1}) \cdot \text{Prob}(S3_t = k \mid Y_{t-1}) && (6)\\
&\text{P}(S1_t = 0 \mid S1_{t-1} = 0) = p_1\\
&\text{P}(S1_t = 1 \mid S1_{t-1} = 1) = q_1\\
&\text{P}(S2_t = 0 \mid S2_{t-1} = 0) = p_2\\
&\text{P}(S2_t = 1 \mid S2_{t-1} = 1) = q_2\\
&\text{P}(S3_t = 0 \mid S3_{t-1} = 0) = p_3\\
&\text{P}(S3_t = 1 \mid S3_{t-1} = 1) = q_3
\end{aligned}
$$

The parameter λ_0 represents the baseline or long-run target rate of inflation, because intended inflation will equal λ_0 when price-level and exchange-rate gaps equal zero in the long run. This parameter is subject to markov switching to capture changes in the long-run desired rate of inflation. From equation (1), note that the partial derivative between today's interest-rate change and λ_0 is negative. Thus, a program of action designed to reduce the trend rate of inflation logically begins with increases in short-term interest rates. Similarly, if the forecast of inflationary pressure associated with a given interest-rate setting were to increase $(\Delta ln\,((1+i)\cdot P)_{t|t-1})$, the model suggests that interest rates will be increased.

The sizes of the feedback coefficients, $\lambda_1(S1_t)$ and $\lambda_2(S2_t)$, determine the rate at which one tries to close price-level and exchange-rate gaps through policy actions. A low feedback coefficient implies that the central bank prefers gradualism as opposed to rapid adjustment and return to the target path. A priori, we would expect German monetary policy to respond primarily to developments in domestic inflation, so λ_2, which measures the strength of exchange-rate feedback, should be relatively small. For Austria on the other hand, exchange-rate feedback, as measured by λ_2, is expected to be large, while some shocks to the domestic price level must be accommodated by limiting the size of λ_1. That is, Austria will sometimes have to import German price level shocks to its own domestic price level.

Equation (2) permits this period's price level target to be a weighted average of last period's actual and target levels plus trend growth. Such rebasing of the targets occurs for values of $\delta_1 < 1$. Consequently, one-time shifts in the price level are gradually accommodated into the target path. As δ_1 decreases from one, the rate of accommodation increases. A similar rebasing scheme is allowed for the implicit exchange-rate target. McCallum (1993) has used a similar weighting scheme, however in his model δ_1 remains constant. We use the same weighting scheme with δ_2 for exchange-rate gaps.

Because of the autoregressive nature of equations (2) and (4), inferences of the state at time t would depend on the entire history of past realizations of the state variables if it were not for the collapsing procedure of equations (3) and (5). Kim (1994) provides the justification for the collapsing procedure and he notes that its use generally introduces a small approximation to the evaluation of the likelihood function in a markov-switching model. He finds, however, that the approximation does not materially affect the parameter estimates.

An independence assumption in equation (6) for the state variables reduces the number of parameters needed for the transition probabilities. With k state variables, each taking on two values, one would need to estimate $(2^k)^2 - (2^k)$ transition probabilities. Whereas with the independence assumption, there are only $2k$ estimated parameters. In our model with three state variables, the reduction due to the independence assumption is from 56 to 6 estimated parameters, so it is necessary to make estimation feasible.

Maximum-likelihood estimates of the parameters are obtained by maximizing the log of the expected likelihood or

$$\sum_{t=1}^{T} ln \left(\sum_{i=0}^{1} \sum_{j=0}^{1} \sum_{k=0}^{1} \text{Prob.}(S1_t = i, S2_t = j, S3_t = k \mid Y_{t-1}) L_t^{(i,j,k)} \right) \tag{7}$$

where the student-t densities are

$$\begin{aligned} lnL_t^{(i,j,k)} &= ln\Gamma(.5(n+1)) - ln\Gamma(.5n) - .5ln(\pi n \sigma^2(S3_t = k)) \\ &\quad -.5(n+1)ln\left(1 + \frac{\hat{\epsilon}(S1_t = i, S2_t = j)_t^2}{n\sigma^2(S3_t = k)}\right) \end{aligned} \tag{8}$$

and Γ is the gamma function.

IV Estimation Results for Germany and Austria

The empirical results, which are presented in the form of parameter estimates, graphs and a goodness of fit test, suggest that German monetary policy is most concerned with the domestic price level as a nominal target, rather than its exchange rate with the U.S. dollar. For Austria, on the other hand, the level of the probability-weighted exchange-rate feedback parameter λ_2 is relatively high throughout our quarterly sample from 1972:1 to 1994:2. The model-implied target path for Austrian inflation suggests that the exchange rate peg to the Deutsche mark is sustainable, because the target path of λ_0 in Austria is on average very close to that in Germany. This parameter hovers slightly above 3.25 percent in Austria, ignoring an upward blip in 1984. In Germany the unconditional value of λ_0 is 2.87 percent, with λ_0=3.50 as the most prevalent state. These values are within one standard deviation of each other, which implies that we cannot detect a significant difference in the long-run inflation targets across the two countries.

Table 2 contains the parameter estimates, where some of the parameters are set to zero according to preliminary estimates of the full model. Figure 3a shows that the model implied target path for German inflation moves in a narrow range between 1 and 4 percent. The model implied target path for German inflation matches the Bundesbank's informal inflation target documented in Table 1 until 1989. The results suggest that the reunification process forced the Bundesbank to take on a slightly higher baseline inflation rate. During the 1990s Germany's baseline inflation path has remained at about 3 percent, although it began falling in 1993. For Germany, the two states for λ_0 are 0.70 and 3.5 percent, with the implied target generally above 3 percent, except for the period 1987-90 when it hovered around 1 percent. Figure 3b shows that the implied inflation target for Austria almost always remains between 3 and 4 percent. The profile of the Austrian target path is within one percent of the German target path for most of the sample. The inflation target path for Austria is nearly constant, due to low persistence in the high inflation state for Austria, as q_1 barely exceeds 0.5.

That the model implies a nearly constant baseline inflation path for Austria might be somewhat puzzling, given the swings observed in Austria's actual inflation performance. To check whether exchange-rate feedback caused Austria's actual inflation to deviate from the baseline rate, that is, whether Austria had to import inflation and disinflation from Germany to maintain the exchange-rate target, we re-ran the model forcing the exchange-rate feedback parameter, λ_2, to equal zero in both states. If exchange-rate feedback were an important source of gaps between actual inflation and the nearly-constant baseline rate, then the estimated baseline rate would have to become more variable if the model allowed exchange-rate feedback to explain fluctuations in Austrian inflation. Figure 3c confirms this conjecture by plotting the estimated baseline rate of Austrian inflation coming from a model that sets $\lambda_2 = 0$ in both states.[4] In the restricted model, the estimated baseline rate

[4]The log-likelihood decreases from the value in Table 2 of -115.2 to -120.7. We cannot use this difference to conduct a standard likelihood-ratio test, however, since p_2 and q_2 are not identified under the null.

of Austrian inflation varies from under 3 percent to more than 6 percent. Thus, failure to include exchange-rate feedback in the model would spuriously lead one to conclude that Austrian monetary authorities have had relatively large swings in their implicit inflation targets. If this were true, the Austrian schilling would not have much credibility with financial markets.

The feedback coefficients from the price level are zero for both Austria and Germany, which implies that past inflation surprises are accommodated immediately. The exchange rate feedback in the high state is .865 for Austria and is zero in the low feedback state. German monetary policy, on the other hand, appears to concentrate on targeting domestic inflation, rather than the exchange rate with the U.S. dollar. For Germany full-model estimates show that λ_2 is essentially zero in both states. The degree of exchange-rate feedback for Austria is best illustrated by weighting the two values of λ_2 by the probabilities of being in the two states. Austrian monetary policy appears to have taken extensive feedback from the exchange rate. Figure 4 illustrates that the feedback parameter on the exchange rate in Austria has varied between 0.2 and 0.8 throughout the sample period, and appears to have settled at about 0.6 now that the exchange rate is very stable. In the late 1970s and early 1980s, the degree of exchange feedback diminished for brief periods. This period coincides with Austria's revaluation of the schilling at the time of the second oil shock. The weighting parameter δ_2 is about .85 in both states, which implies that Austrian monetary policy essentially maintains an exchange-rate target in levels, rather than accommodate past shocks rapidly.

We find substantial heteroskedasticity in the residuals for both countries, as the standard deviations, which equal

$$\sigma\left(\frac{n}{n-2}\right)^{.5}$$

from equation (1), switch between .43 and 1.71 for Germany and .23 and 1.49 for Austria. Thus, the standard deviation changes by at least a factor of four between the two states. Statistical tests aiming to demonstrate the significance of markov switching, however, are hampered by the fact that the transition probabilities are not identified under the null of no switching. Hansen (1992) discusses this issue and presents a simulation methodology to arrive at empirical estimates of the critical values for likelihood-ratio tests. Because the simulations required for each critical value take a substantial amount of computer time, we do not pursue that strategy. Instead, we present goodness-of-fit tests of the model's specification. With respect to heteroskedasticity specifically, we note that markov switching in the variances reduces the serial dependence in the squared residuals from that in the squared dependent variable: The Box-Pierce statistics for Austria go from 56.8 in the raw data to 31.9 in the squared residuals. These statistics do not have a standard Chi-square distribution, however, because the residuals are not assumed to be normal and *i.i.d.*

As a formal test of the model specification, we present goodness-of-fit test statistics, rather than a series of likelihood ratio tests, because, as noted above, the LR test statistics have nonstandard distributions when parameters (transition probabilities) are not identified under the null. We divide the 90 observations into 10 groups based on the probability of observing a value smaller than the actual residual. If the model's time-varying density function fits the data well, these probabilities should be uniformly distributed between zero and one. Following Vlaar and Palm (1993),

$$n_i = \sum_{t=1}^{T} I_{it} \qquad \text{where} \qquad \begin{aligned} I_{it} &= 1 \quad \text{if} \quad \frac{(i-1)}{10} < EF(\epsilon_t, \hat{\theta}) \leq \frac{i}{10} \\ &= 0, \quad \text{otherwise} \end{aligned}$$

The expected value of the cumulative density function is taken across the eight combinations of the three states that might have held at each time, where F is the student-t cumulative density for Austria and the standard normal cumulative density for Germany and $\hat{\theta}$ is the parameter vector.

The goodness-of-fit test statistic equals $T/10\sum_{i=1}^{10}(n_i - T/10)^2$ and is distributed χ^2_9 under the null. The specifications are not rejected for either Austria or Germany, because their test statistics equal 6.4 and 5.6, respectively, neither of which is rejected as a χ^2_9 variate.

Overall, the indicator model provides a general framework for a multiple-objectives feedback mechanism. Application to both Germany and Austria returns the expected finding that German monetary policy has been most concerned with the domestic price level, rather than the exchange rate. Since the indicator model uses the changes in the short-term interest rate instrument as the policy information variable, it is important to check that the model reasonably describes actual policy actions. Figure 5a illustrates the ability of the feedback model to explain changes in Germany's short-term interest rate. The model does quite well in explaining the direction and volatility of interest-rate changes, except in the early 1970s when the model called for tighter policy than actually occurred. Interestingly, the model also overpredicts Germany's short-term interest rates in the post-reunification 1990s. Actual changes in Austria's interest-rate differential with Germany are plotted with the model-implied changes in Figure 5b. The model successfully captures the large decrease in the volatility of the interest-rate differential that has take place as the exchange-rate peg has become tighter and more and credible.

Conclusions

A test is developed that determines whether the current monetary settings are consistent with a central bank's pre-announced target, which could be an exchange-rate target, an inflation target, or some other nominal target. We test the sustainability of an exchange-rate peg by comparing the implicit inflation targets between the anchor and pegging countries. To identify the implicit inflation targets, an indicator model is used which includes domestic price and exchange rate feedback. The proposed test is applied to the Austrian experience of exchange rate targeting, however Dueker and Fischer (1995) also show that estimating the inflation target path has extended application for evaluating the performance of central banks that have announced explicit inflation targets.

Our empirical results find that Austria's hard currency policy has proven to be sustainable, because the path of the Austrian implicit inflation target converged quickly to a level very near the German target. The differential between the implicit inflation targets for the two countries is estimated to be less than one percent on average for our sample period, 1973-1994. In fact, we find Austria's implicit long-run inflation target to be nearly constant, so that fluctuations in Austrian inflation are largely due to the need to import inflation and disinflation from Germany as needed to maintain the exchange-rate target.

We also note that because the indicator model allows for multiple feedback variables, we could incorporate information from futures markets or expectations of future inflation embedded in bond yields, as in Svensson (1994). Addition of feedback from such forward-looking variables is a topic of future research.

Appendix

The interest rate forecasts for the indicator model are based on a model by Kim (1994), which allows for two types of uncertainty. The first arises from heteroskedasticity in the error terms. This is modelled by a markov switching process, which tries to match the persistence of periods of high and low volatility in the data. The second source of uncertainty arises as economic agents are obliged to infer unknown or changing regression coefficients.

The variable i is the 3-month Euro rate and P is the consumer price index. The model generating the forecasts is

$$\begin{aligned}
\Delta ln\left((1+i)\cdot P\right)_t &= \beta_{0t} + \beta_{1t}\Delta ln(1+i)_{t-1} + \beta_{2t}\Delta ln P_{t-1} + \beta_{3t}\Delta ln\left((1+i)\cdot P\right)_{t-1} + e_t \qquad (9)\\
& e_t \sim \text{Normal}(0, h_t)\\
h_t &= \sigma_0^2 + (\sigma_1^2 - \sigma_0^2)S_t\\
& S_t \in \{0,1\}\\
& \sigma_1^2 > \sigma_0^2
\end{aligned}$$

$$\begin{aligned}
\text{Probability}(S_t = 0 \mid S_{t-1} = 0) &= p_1\\
\text{Probability}(S_t = 1 \mid S_{t-1} = 1) &= p_2
\end{aligned}$$

The variances of the error terms are assumed to switch between a low and a high state according to a first-order markov process. Persistence of low and high volatility states is increasing in p_1 and p_2, respectively. Note that the markov switching in the forecast equation (9) is separate from the markov switching in the interest-rate equation (1).

The time-varying coefficients, assume that the state variables, β_t follow a random walk process:

$$\beta_t = \beta_{t-1} + v_t \tag{10}$$

$$v_t \sim \text{Normal}(0, Q)$$

The random walk assumption suggests that agents need information before changing their views about the relationships among variables.

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Table 1: Informal Inflation Targets for Germany	
year	**Unavoidable Inflation**
1975	4.5
1976	4.5
1977	3.5 “less than four”
1978	3
1979	3 “no new inflation”
1980	4
1981	3.8
1982	3.5
1983	3.5
1984	3
1985	2.5
1986-1994	2.0
Source: von Hagen (1994).	

Table 2: Indicator Models for Germany and Austria		
parameter	**Germany**	**Austria**
$\lambda_0(S1=0)$	3.497 (.371)	6.797 (1.447)
$\lambda_0(S1=1)$	0.710 (.553)	3.246 (.229)
$\lambda_1(S1=0)$	0	0
$\lambda_1(S1=1)$	0	0
$\delta_1(S1=0)$	n.a.	n.a.
$\delta_1(S1=1)$	n.a.	n.a.
$\lambda_2(S2=0)$	0	.8648 (.379)
$\lambda_2(S2=1)$	0	0
$\delta_2(S2=0)$	n.a.	0.8534 (.169)
$\delta_2(S2=1)$	n.a.	0.8406 (.231)
$\sigma^2(S3=0)$	0.189 (.043)	0.0244 (.012)
$\sigma^2(S3=1)$	2.93 (.836)	0.9937 (.397)
p_1	0.969 (.034)	0.5179 (.383)
q_1	0.895 (.080)	0.9545 (.053)
p_2	n.a.	0.9068 (.117)
q_2	n.a.	.0.8593 (.133)
p_3	0.968 (.024)	0.9466 (.043)
q_3	0.947 (.043)	0.9659 (.027)
$\frac{1}{n}$	0	.275 (.147)
Log-Likelihood	-111.33	-115.21
No. of parameters	8	14

Note: Standard errors are in parentheses.
Some of the parameters are set to zero
based on preliminary estimates of the full model.
If feedback parameters are zero in both states, δs are not identified.

Figure 1

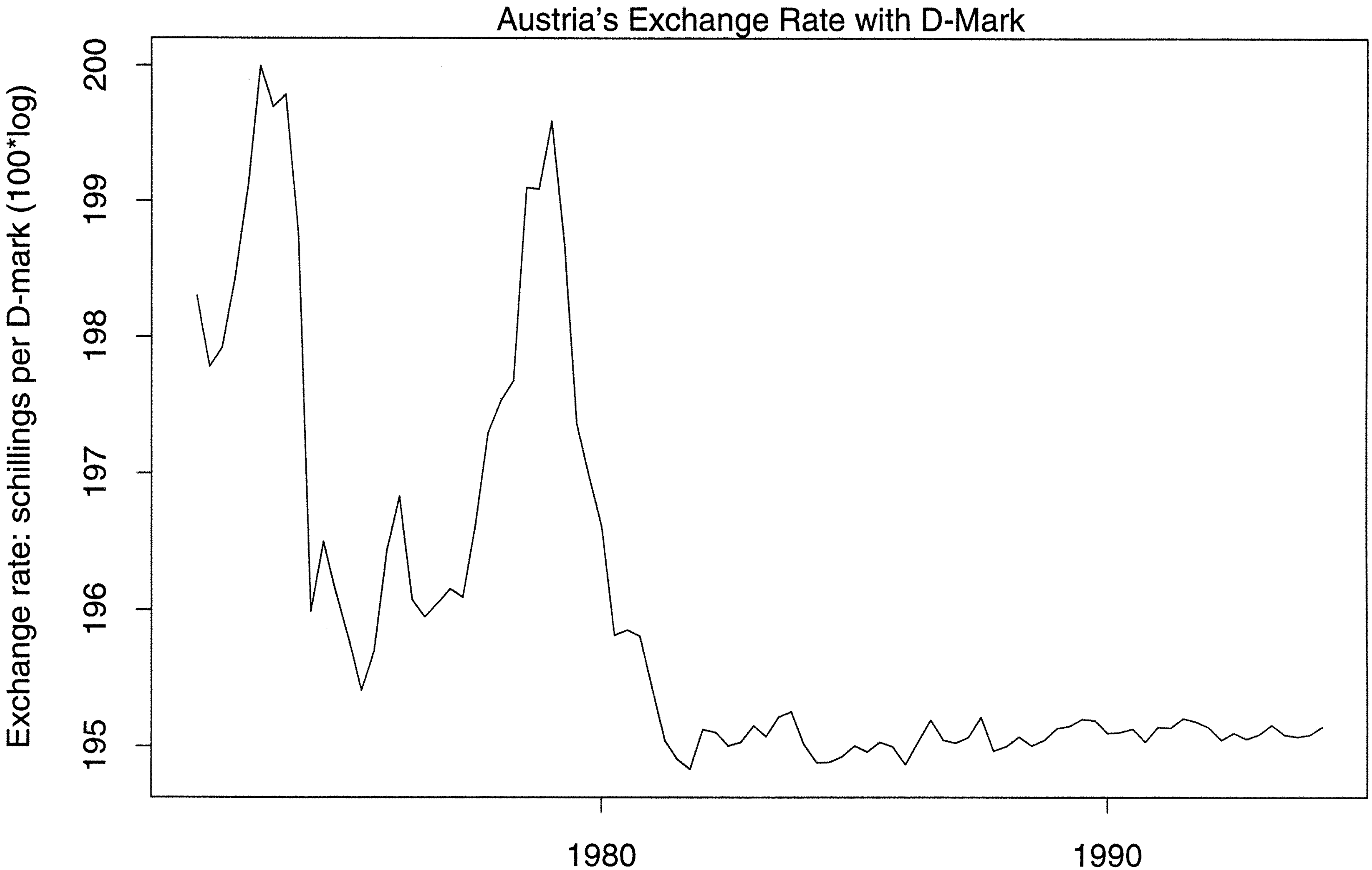
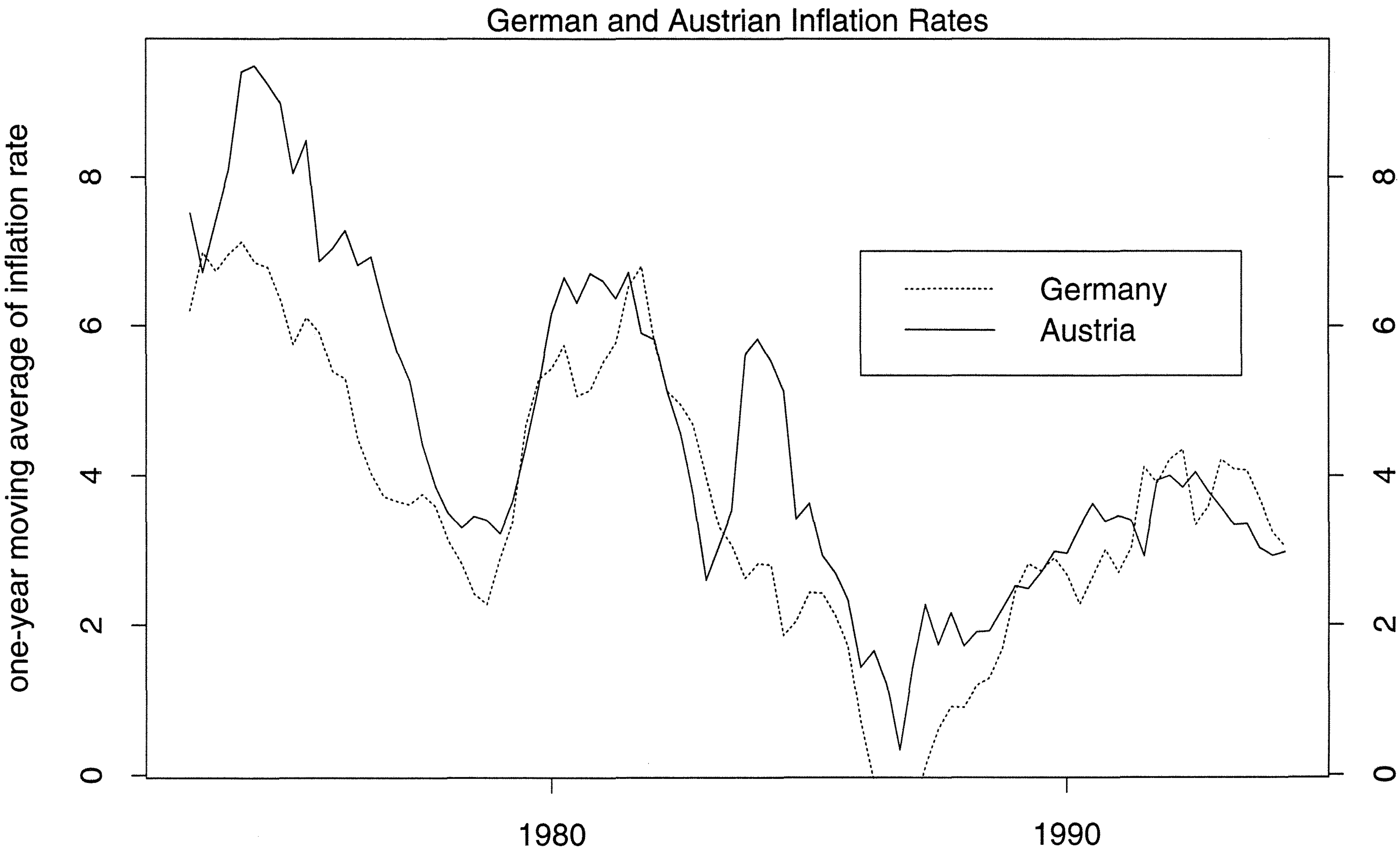
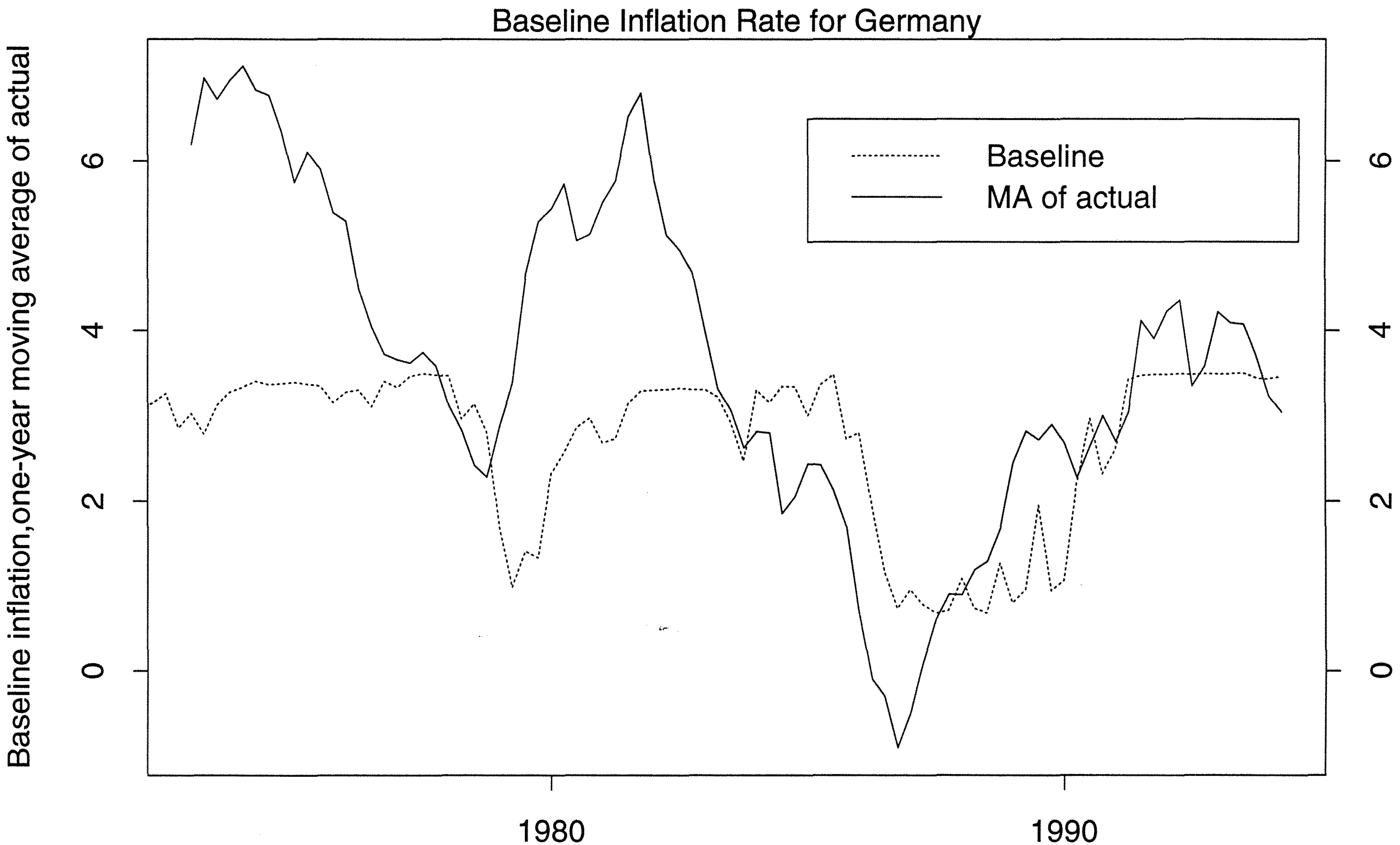

Austria's Exchange Rate with D-Mark
Exchange rate: schillings per D-mark (100*log)
200
199
198
197
196
195
1980
1990

Figure 2



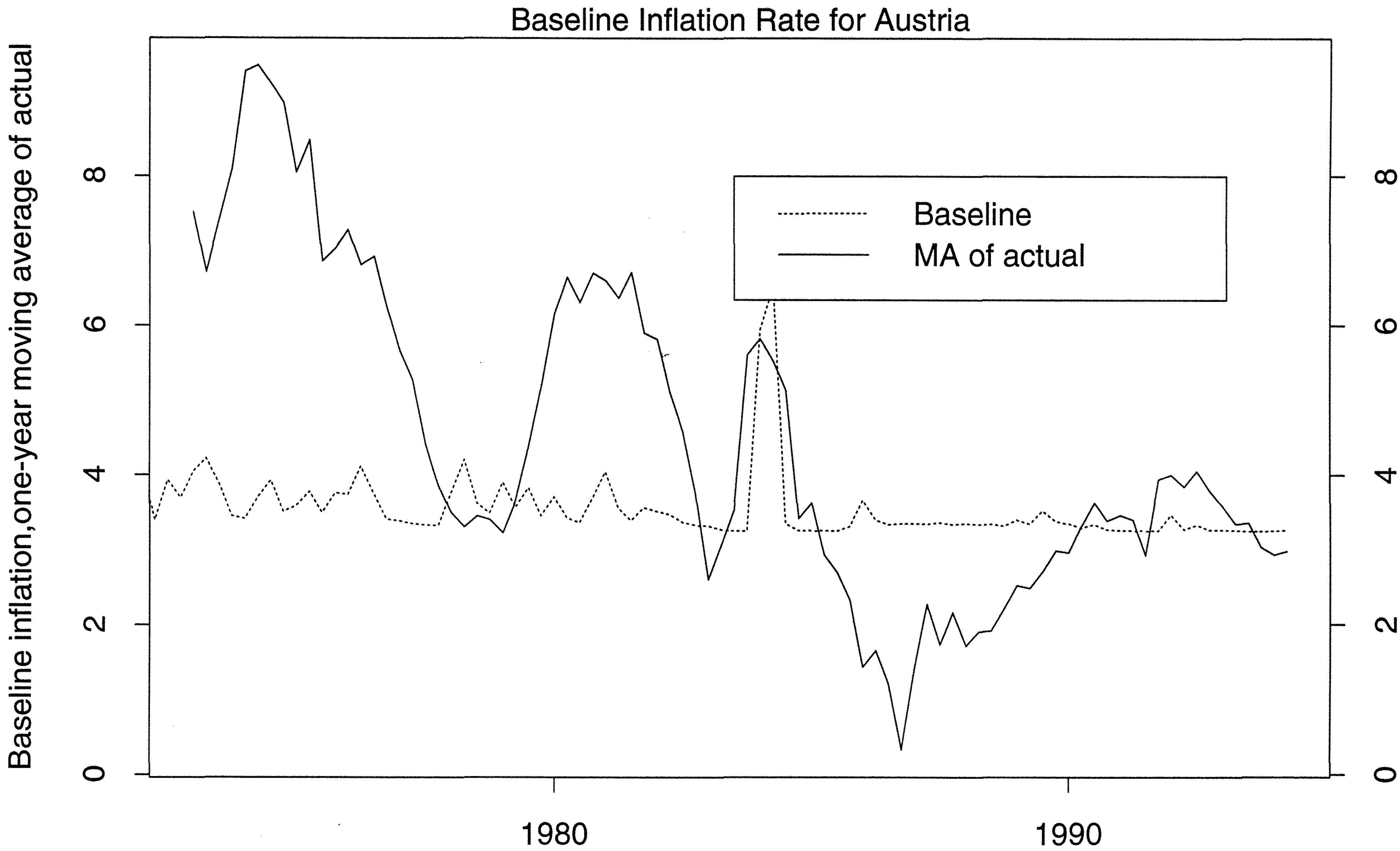
German and Austrian Inflation Rates
one-year moving average of inflation rate
0
2
4
6
8
1980
1990
Germany
Austria

Figure 3a



Baseline Inflation Rate for Germany
Baseline inflation,one-year moving average of actual
Baseline
MA of actual
0
2
4
6
1980
1990

Figure 3b



Baseline Inflation Rate for Austria
Baseline inflation,one-year moving average of actual
Baseline
MA of actual
0
2
4
6
8
1980
1990

Figure 3c

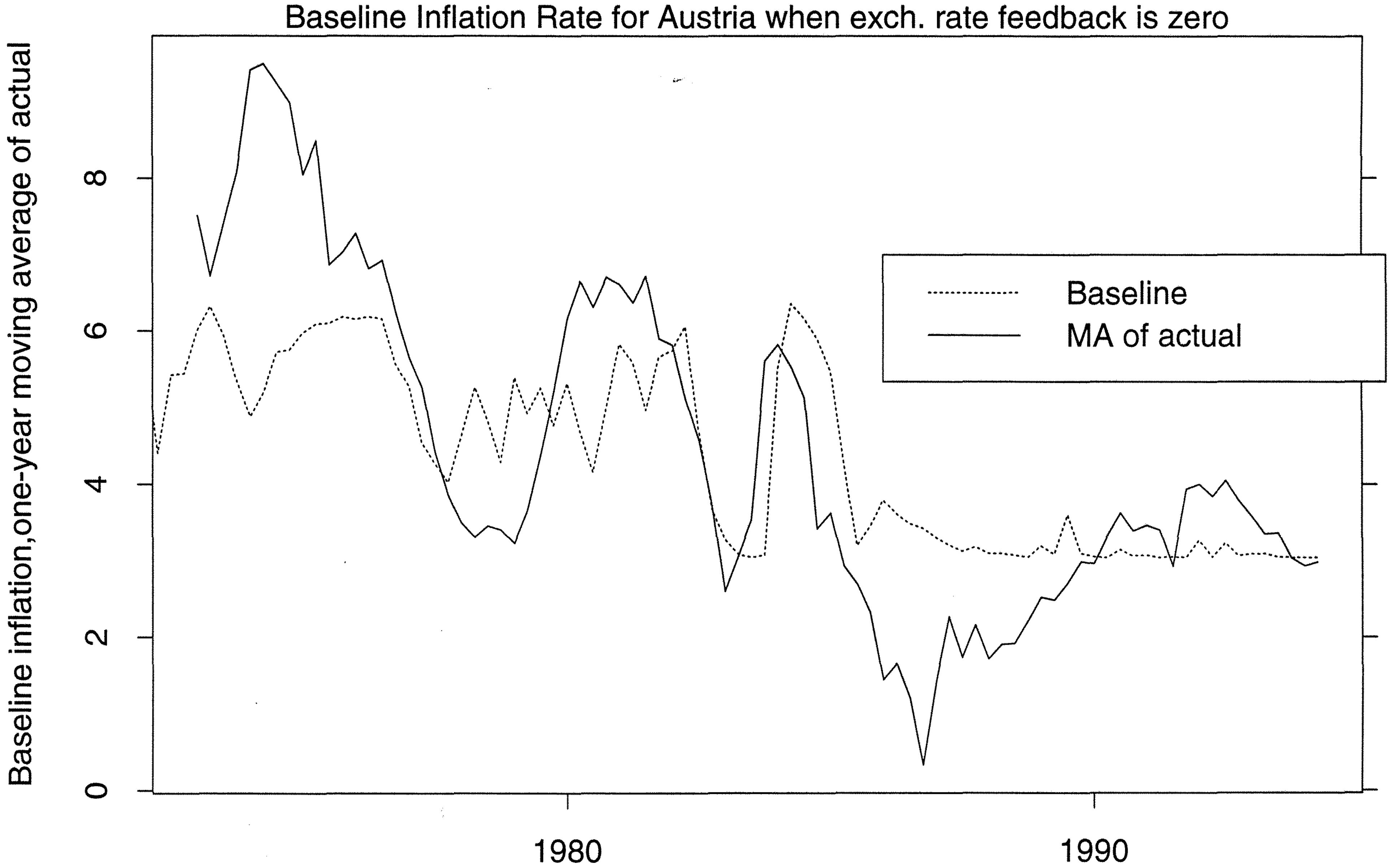

Baseline Inflation Rate for Austria when exch. rate feedback is zero
Baseline inflation,one-year moving average of actual
0
2
4
6
8
1980
1990
Baseline
MA of actual

Figure 4

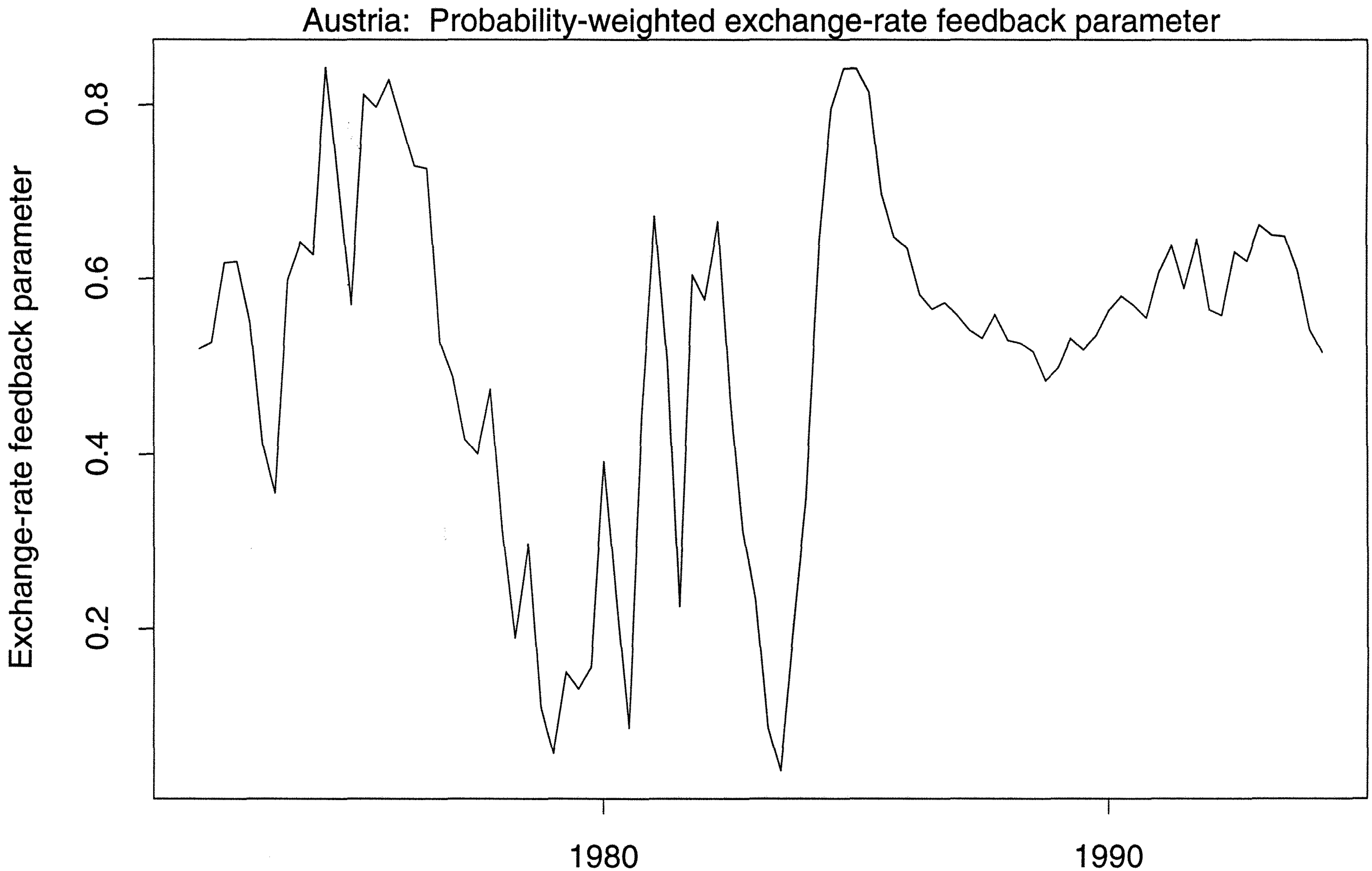

Austria: Probability-weighted exchange-rate feedback parameter
Exchange-rate feedback parameter
0.2
0.4
0.6
0.8
1980
1990

Figure 5a

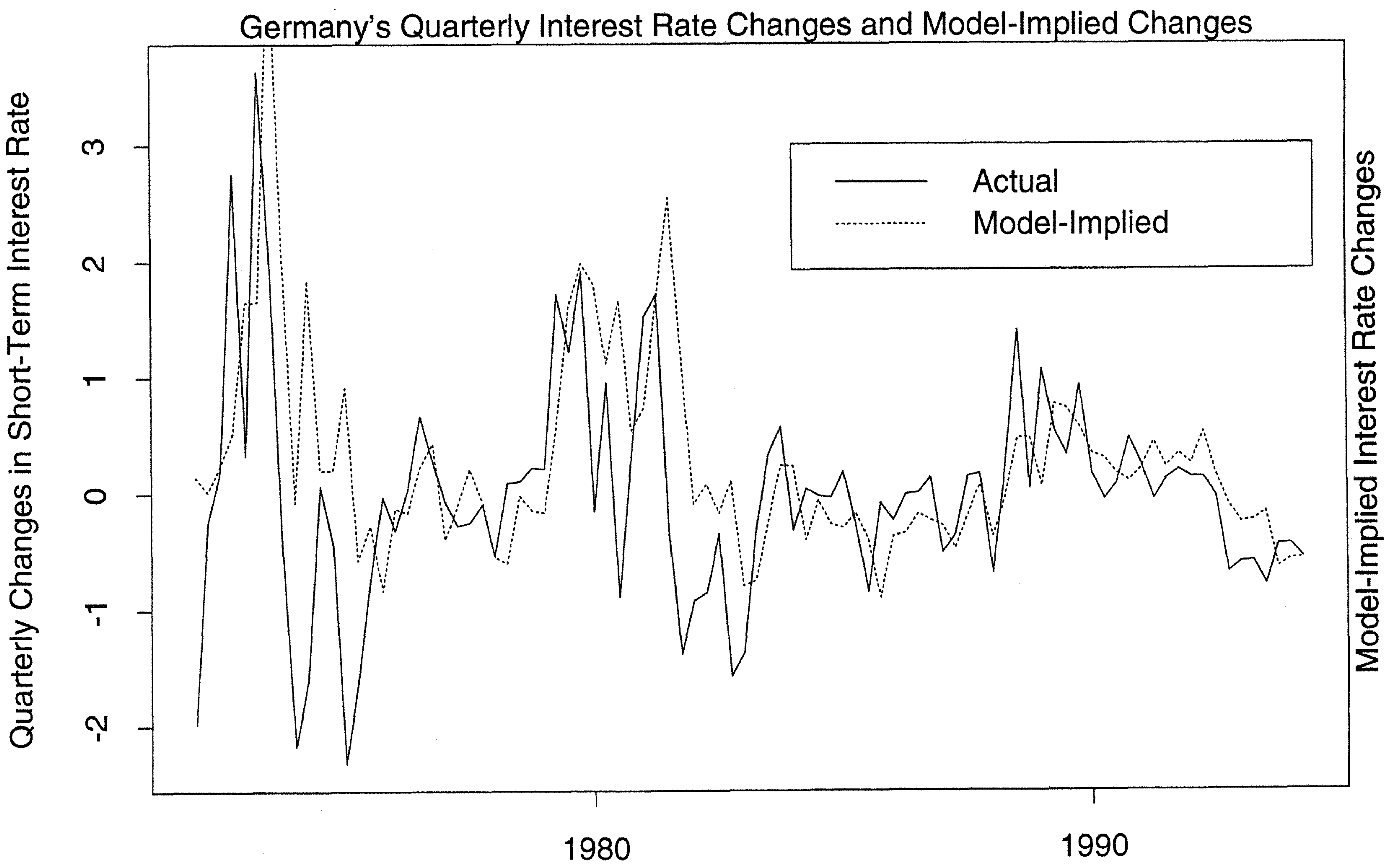
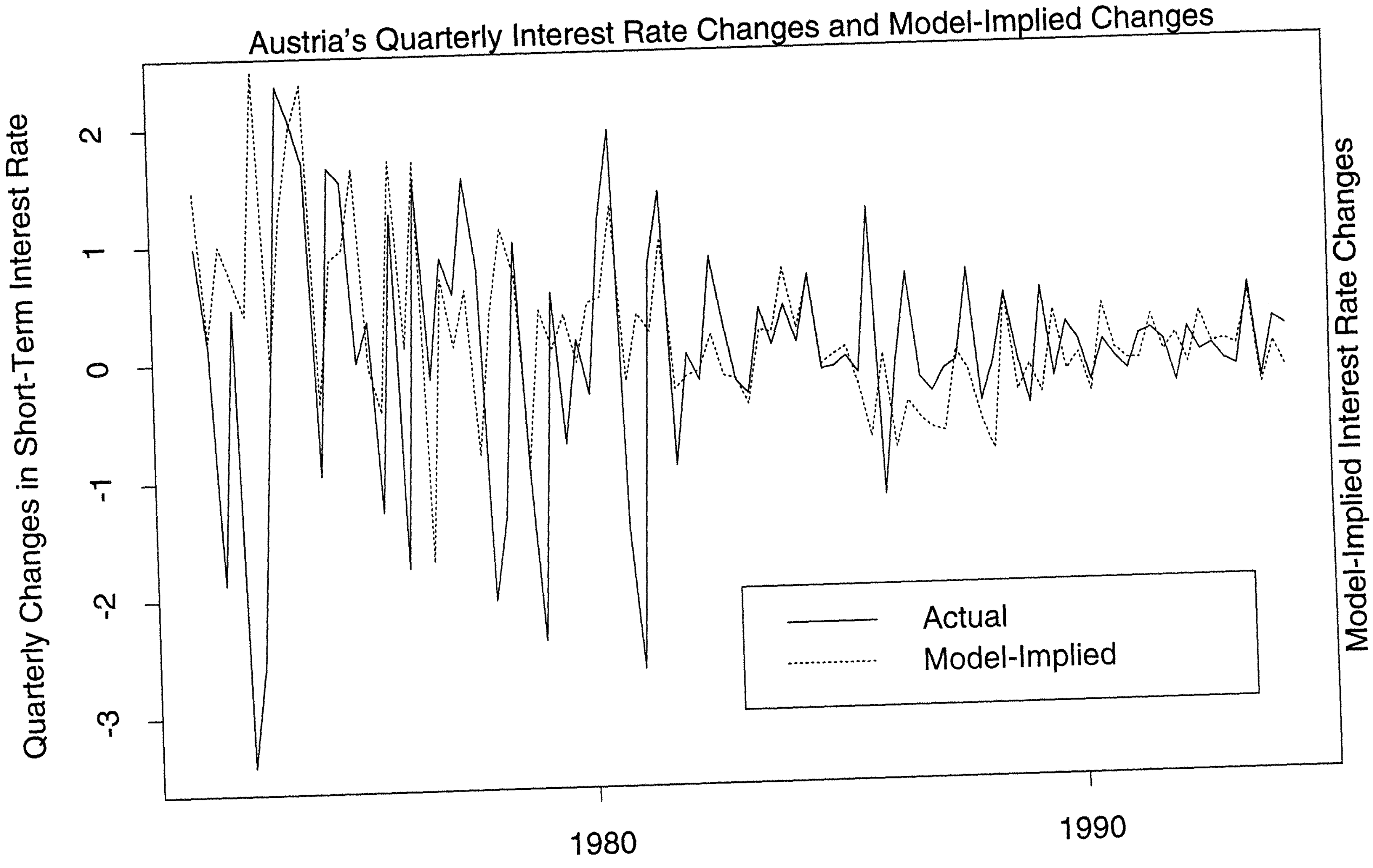

Germany's Quarterly Interest Rate Changes and Model-Implied Changes
Quarterly Changes in Short-Term Interest Rate
Model-Implied Interest Rate Changes
-2
-1
0
1
2
3
1980
1990
Actual
Model-Implied

Figure 5b



Austria's Quarterly Interest Rate Changes and Model-Implied Changes
Quarterly Changes in Short-Term Interest Rate
Model-Implied Interest Rate Changes
2
1
0
-1
-2
-3
1980
1990
Actual
Model-Implied